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IDENTIFYING THE STUDENTS' PROPORTIONAL REASONING

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ABSTRACT

Proportional reasoning is one of the most important abilities to be developed during the middle grades. Using proportional reasoning, students consolidate their knowledge of elementary school mathematics and build a foundation for high school mathematics. The aim of this study is to identify students' proportional reasoning. In order to do so, a literature study was carried out on students' proportional reasoning. After that, an individual written test on ratio and proportion was done, followed by a brief interview. Twenty-five students from grade seven did the written test and interviewed. Data analysis revealed that student was trying to use cross-product in inappropriate problem, avoid form an equation, a student was trying to unitizing but got stuck when adenominator is a large number, student still struggle at inversely proportional problem.

KEYWORDS: Identifying, Proportional Reasoning, Ratio, Proportion & Indonesian Student

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Original Article

INTRODUCTION

The proportion may be the most commonly applied mathematics in the real world (Hoffer, 1988). Beyond the mathematics classroom, proportional reasoning is evident in other subject areas like science, music, and geography, as well as in everyday activities (Ontario Ministry of Education). People use proportional reasoning to calculate best buys, taxes, and investments, to work with drawings and maps, to perform a measurement or monetary currency conversions, to adjust recipes or to create various concentrations of mixtures and solutions. Understanding of proportionality is also central to mathematics; Proportional reasoning is one of the most fundamental topics in middle grades mathematics (Ellis, 2013). Susan Lamon estimates that over 90% of students who enter high school cannot reason well enough to learn mathematics and science with understanding and are unprepared for real applications in statistics, biology, geography or physics (Lamon, 2005).

The Common Core State Standards for Mathematics and the NCTM Principles and Standards for School Mathematics both include proportionality in their standards for the middle school mathematics curriculum (National Governors Association, 2010; National Council of Teacher of Mathematics, 2000). In Indonesia, students learn ratio and proportion at fifth and seventh grade based on Permendikbud year 2016.

Proportional reasoning must be developed over a long period of time, not a single unit or chapter (Langrall, 2000). Proportional reasoning is one of the most important abilities to be developed during the middle grades. Using proportional reasoning, students consolidate their knowledge of elementary school mathematics and build a foundation for high school mathematics. So it is useful for identifying the students' reasoning and the areas in which they applied incorrect reasoning strategies (Hilton, A., Hilton, G., Dole, S., & Brien, M. O., 2012).

THEORETICAL BACKGROUND

Proportional Reasoning

Lobato & Ellis (Ellis, 2013) define proportional reasoning as a relationship of equality between two ratios. Here are a few examples that provide further clarification of some proportional reasoning concepts:(Cited from “Paying attention to proportional reasoning K-12: Supporting Document for Paying Attention to Mathematical Education”).

Unitizing and Spatial Reasoning

These concepts involve being able to envision a particular quantity in same-sized groupings (or quantity sets) and being able to conceptualize them as units. For example, a dime can be considered as both 1 dime and 10 cents simultaneously. The unit is the dime, so 3 dimes represent 3 units – each worth 10 cents.

Multiplicative Thinking

This concept involves reasoning about several ideas or quantities simultaneously. It requires thinking about situations in relative rather than absolute terms. Consider the following problem. If one dog grows from 5 kilograms to 8 kilograms and another dog grows from 3 kg to 6 kg, which dog grew more? When a student is thinking in absolute terms or additively, she/he might answer that both dogs grew by the same amount. When a student is thinking in relative terms, she/he might argue that the second dog grew more since he doubled his previous weight, unlike the first dog who would have needed to be 10 kg to grow by the same relative amount. While both answers are viable, it is the relative (multiplicative thinking) that is necessary for proportional reasoning.

Understanding Quantity Relationships and Change

These concepts involve thinking about how quantities relate, co-vary or change together (how a variation in one quantity coincides with the variation in another). Consider the following example: Every time you buy one pack of gum, you get 5 sports cards. For 10 packs, you get 50 cards. The total number of cards you get (C) is dependent upon the number of packs of gum you purchase (P) so that $C = 5 \times P$ or $C = 5P$.

Partitioning, Measuring, Unit Rates and Spatial Reasoning

These concepts are linked to proportional reasoning because they involve reasoning about the equal splitting of a whole, determining relative location and comparing measures of two different things through strategies such as guess and check, measuring, a successive division of a unit and/or calculating differences. This can involve reasoning about two data points to find a third.

Understanding Rational Numbers

Rational numbers are numbers that can be expressed as fractions; they can be challenging for students to grasp since they must see numbers expressed in relation to other numbers rather than as a fixed quantity, like whole numbers. Consider the following problem: Describe a situation when one third is greater than one half.This can be challenging if students have not had experience with comparing fractions in relation to their wholes. For example, one- third of a jumbo-sized chocolate bar can be much larger than one half of a mini chocolate bar.

Research Question

We consider that identifying and understanding student solving scale, ratio, percentage, inversely proportion that

can lead to a better insight into how student really constructs their proportional reasoning. Different problem types elicit different solution strategies regardless of a student's level of understanding of proportional reasoning **(**Lamon, 1993).

Therefore, we focus on this research question:

How students construct their proportional reasoning?

It was useful for identifying the students' reasoning and the areas in which they applied incorrect reasoning strategies (Hilton, A., Hilton, G., Dole, S., & Brien, M. O., 2012).

METHODS

To address the research question, the author conducted an explorative study in which an individual written test on proportional reasoning problem, followed by student interviews on their work.

Sample

The subject of the study was 20 Indonesian students taken from grade VIII were involved in 2017. They finished grade VII (13/14 -year-old), in which they had studied ratio and proportion.

Data Collection

Data were collected by written task and follow-up interviews. First, students were asked to solve a set of tasks about proportional reasoning with paper and pencil individually forty minutes. Students were informed that their solutions would not be graded so they would feel free to use their own solution. The goal of this written test was to identify how students construct their proportional reasoning.

This time was used to select students' written work based on a preliminary selection made through observation during the written test. The interviewer selected students for the additional individual interviews, which had as a goal to gather more detailed data about student's reasoning.

The interviews were conducted and recorded on a different day as the written test and took about twenty minutes. They were encouraged to explain their reasoning. The general interview questions included: What do you understand from this problem? What do you not understand from this problem? Which part of the problem that makes you confused? How did you solve this problem? Could you explain your solution? The follow-up questions included, for instance: Why did you make this step? What did you mean by this step? What does it mean? The former type of questions was used at the beginning of an interview, and the latter was used while the interview was taking place and depended on students' responses.

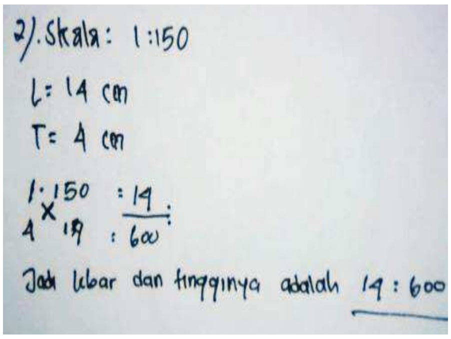
If a student did not solve one of the tasks, the interviewer asked whether he or she understood the task and then asked further questions. The interviewer would ask him or her to read the task aloud to identify whether the student really understood the problem. The interviews revealed that this was caused by their inability to solve the task and not by a lack of time, cause most of the student avoid the problem about how to make an equation from ratio problem.

Tasks

The tasks used in this study, all the proportional reasoning problems on ratio, proportion, percentage topic, were taken from Indonesian mathematics textbooks for students in grade VII. The tasks concern proportional reasoning. The

tasks were spread randomly so that each student was randomly assigned.

RESULT AND DISCUSSIONS



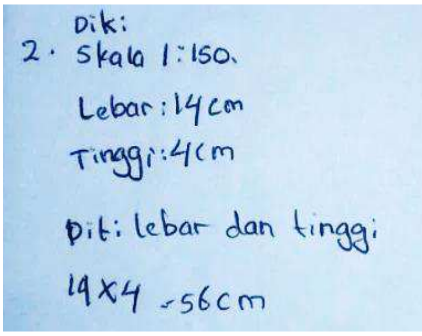


Figure 1: Student Answer UsingFigure 2: Student's Written Work on Task 2 Cross MultiplicationStruggling Understanding Rational Numbers

Student's written work on task 2 struggling understanding rational numbers shown in Figure 1 and 2. It is obvious in Figure 1 student was trying to solve the problem by using cross multiplication but it is not appropriate strategy to solve the problem. The procedure does not match the mental operations involved in the building up strategy, and the cross product lack meaning in any given situation (Ellis, 2013).It is obvious that student does not understand the problem.Based on interview, student does not understand the meaning of "1:150". She thought 1 is the number of the house. That is an unrelevant answer, she just trying to give a random answer. Figure 2 student just multiply the length and height of the building without attempting using proportional reasoning at all.

Many curricula emphasize procedures and skills for solving proportions, but researchers caution that the most important challenge of developing students' capacity to reason proportionally is to teach ideas and to restrain the quick path to computation (Smith, 2002). The way to teach proportion by giving a ready used-formula remains meaningless for the students. They may just memorize the procedure of cross multiplication without understanding about the insight of proportionality itself. The question may not be whether the proportion algorithm should be taught so much as when; if the students are not yet reasoning proportionally and have not yet formed a ratio, then the proportion algorithm could be harmful to their understanding (Ohlsson & Ress, 1991; Smith, 2002). Formally setting up proportions using variables and applying the cross-product rule should be delayed until after students have had an opportunity to build on their informal knowledge and develop an understanding of the essential components of proportional reasoning (Langrall, 2000).

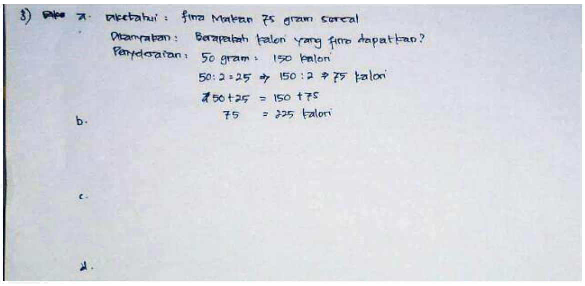


Figure 3: Student's Written Work on Task 3who use Additive and Multiplicative Reasoning

Most of the students solving this question by finding unitizing and the rest of students left the answer blank. Figure 3 shows that eventhough student did not find the unit of the problem, the answer remains correct. He solves the

problem at different strategy than his friend. He clearly explains that he is finding the calorie for 25 gram by halving 50 gram. Then, he adds together 50 gram and 25 gram to get 75 gram. He did the same to count the calories until he arrived at the answer 255 calories. The strategy reveals an understanding of proportional reasoning and multiplicative thinking involving halves. Helping students bridge from additive to multiplicative thinking is complex but starts early.It requires time, a variety of situations and opportunities to construct their understanding in multiple ways. Although composed units are typically easier for middle grades student to begin forming ratios, it is also important that they learn to form multiplicative comparisons and understand how they are connected to composed units (Ellis, 2013).

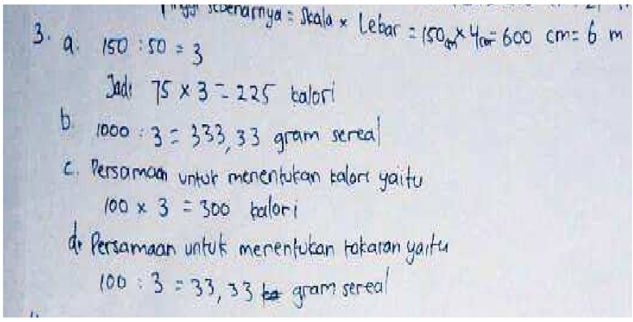


Figure 4: Student's Written Work on Task 3 Who did not know to Form an Equation

Everytime we consume 1 gram of cereal, we get 3 calories. The total amount of calories we got is dependent upon the amount of gram we consume. So, that $k = 3t$ "the amount we consume" is a variable that has proportionate calories based on we consume.

Most of the student did not answer the question which asks to form an equation. As shown at Figure 4 the rest of students who were trying to solve the problem were struggling to form an equation (3c and 3d). These tasks involve thinking about how quantities relate, co -vary or change together.It has been clarified that student did not lack time, it because they did not know to form an equation.

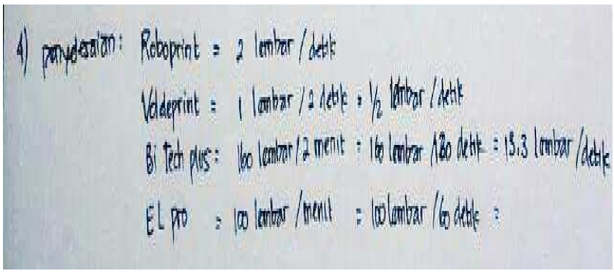


Figure 5. Student's Written Work on Task 4 on Unitizing use a Second

By Figure 5 It seems that student was trying to unitizing but got stuck when a denominator is a large number (such as 120 second and 60 seconds). But, the student got answer correctly for the speed of Roboprint and Voiceprint cause donominator of them are the small number (one and two seconds). If the unit is a second, two second or even a minute then the answer will remain the same. It is depending on the unit that student choose. It is critical to spend time developing unitizing since the ability to use composite units is one of the most obvious differences between students who reason well with proportions and those who do not (National Research Council, 2001).

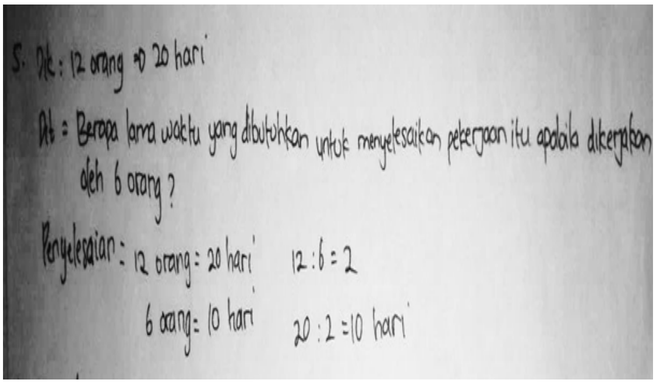


Figure 6: Student's Written Work on Task 5

The student should focus on the relationship rather than the numerical quantities. By focusing on change, students develop an intuition about evaluating their final answers. Figure 6 shows that student incorrectly use a proportion the time will decrease instead of increase. Fewer people work on the project require much time to complete the project.

Prior to the study of change in algebra students need to develop a language for describing and talking about change, a way to categorize change and develop representations for the types of change they encounter (McIntosh, 2013). Most of a student's knowledge of change is intuitive and built on personal experience. Proportional reasoning requires that students can evaluate and compare the relationship between two quantities and how they change. Students need to be able to identify an inversely proportional situation as proportional in order to attain mastery of the first critical component (Holzrichter, 2016).

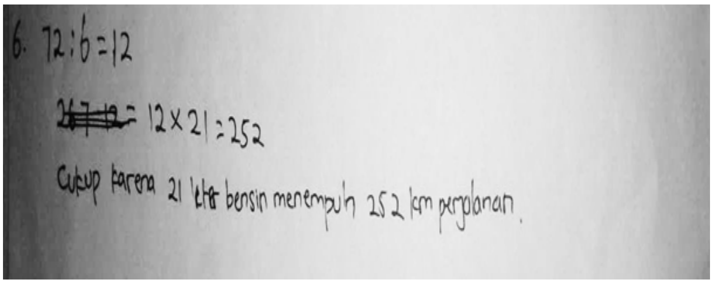


Figure 7: Student's Written Work on Task 6 who Understand Multiplicative Approach but Incorrectly to Draw a Conclusion

Figure 7 shows that student can recognize and understand the additive and multiplicative approaches. Student correctly decides 12 km which can be taken for one liter of gasoline. Student correctly calculate the distance that can be reached by spending 21 liters of gasoline.Although the student did not write the explanation in the word, a student just writes the calculation. If students recognize and understand the difference between the additive and multiplicative approaches, this is a beginning to being able to reason proportionally (Van de Walle, 2010).

One possible reason she was at a loss to make a conclusion about is it the gasoline enough to get through 267 km was because it did not fall into the typical format with three given number and one missing number. It makes student confused to decide a conclusion cause student get a new number 252 km, student miss to compare it with 267 km.

CONCLUSIONS

Data analysis revealed that student was trying to use cross-product in an unappropriate problem, avoid form an equation, the student was trying to unitizing but got stuck when a denominator is a large number, the student still struggles at an inversely proportional problem.

LIMITATION

This study has several limitations to mention. First, a component of assessing students' proportional thinking is not quite obvious, cause many literature mentions different components. Second, the task should highly concern students' proportional reasoning and require high order thinking. This study only givesa limited possible reason why students encountered the difficulties. Because of it, a deep interview is needed for more. Third, It has only been applied to a small sample of students and to a specific of proportional reasoning. So further research is needed.

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